The Evolution of Connected Vehicle Technology: From Smart Drivers to Smart Cars to… Self-Driving Cars

Vehicle-to-vehicle and vehicle-to-infrastructure technology promise to change the way we move on our roads. Siva R. K. Narla, senior director, Transportation Technology, Institute of Transportation Engineers, Washington, DC, USA, writes about how the research for these technologies is shaping the travel scene in the United States and Europe.

BY SIVA R. K. NARLA

DRIVER'S EDUCATION MANUALS in the next decade could start with an opening sentence that reads, "Your car talks to other cars, to traffic lights, and to other roadside devices, and the roadway talks to your car too." One has to wonder where vehicle-to-vehicle (V2V) technology is taking us, as each generation of cars is equipped with smarter technology than the last. The true sign of any technology's integration and its usefulness is when people intuitively adapt to it. V2V and vehicle-to-infrastructure (V2I) technology initiatives are attempting to provide a framework that helps users transition to the future of driving as seamlessly and intuitively as possible. These initiatives are also collectively referred to as V2X technology in the United States and Car2x in Europe. This article is intended to help put the evolution of the technology into perspective for visualizing the change coming in the future without the hype and promises that almost certainly accompany such a transformation.

ITS and GPS Technologies: Building the Foundation for the Smart Driver Transformation

The last two decades of innovation in transportation technology has been about providing better information to the user. An informed user is a smart driver. From an infrastructure technologies' perspective, this improved information exchange has been made possible through the use of intelligent transportation systems (ITS) with improved telecommunications and centralized traffic management that has informed the user to varying degrees of success. Global positioning system (GPS)-based services and in-vehicle safety systems have driven the vehicle-based transportation technology innovation. Information technology (IT) and telecommunication standards and protocols underlying these ITS, GPS, and in-vehicle technologies have become the framework for the newer connected vehicle (CV) technologies coupled with other newer standards being developed.

How Does Connected Vehicle Technology Work?

V2V communication is being architected as a framework for real-time, short-range wireless data exchange between vehicles that will provide significant safety benefits. According to the U.S. Department of Transportation (USDOT), CV technology enables the exchange of anonymous, vehicle-based data regarding position, speed, and location.V2V communications enable a vehicle to detect threats and hazards with a 360-degree awareness of the position of other vehicles, as well as the threat or hazard those vehicles present; calculate risk; issue driver advisories or warnings; and take pre-emptive actions to avoid and mitigate crashes. At the heart of V2V communications is a basic application known as the "*Here I Am*" data message. This message is currently envisioned to be dedicated short-range communication (DSRC) based, but it can also be derived using non-vehicle-based technologies such as GPS to identify the location and speed of a vehicle or vehicle-based sensor data, which would derive the location and speed data from the vehicle's computer and combine it with other data such as latitude, longitude, or angle to produce a detailed situational awareness of other vehicles' positions.

The vision for V2V is that eventually each vehicle on the roadway (automobiles, trucks, buses, motor coaches, and motorcycles) will be able to communicate with other vehicles, and this rich set of

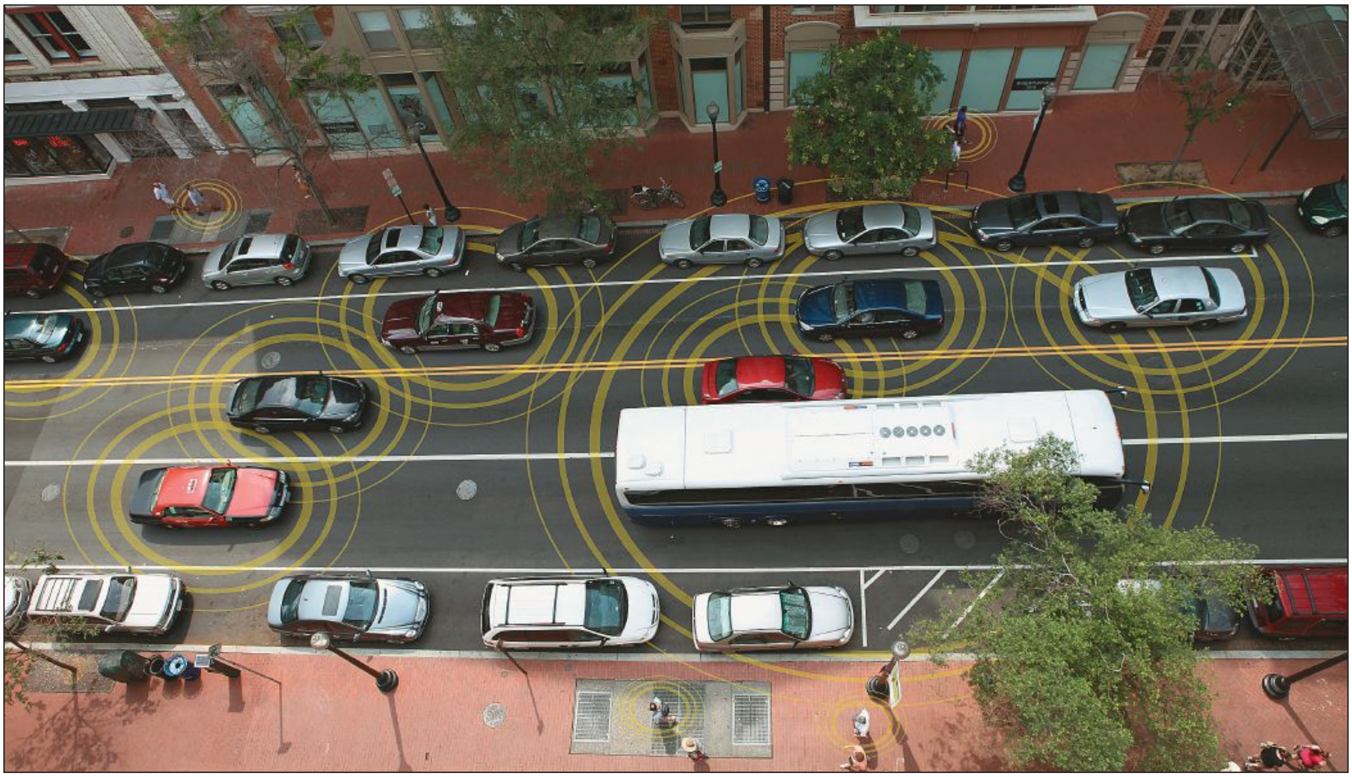

Figure 1. Vehicle-to-vehicle (V2V) communication is being architected as a framework of real-time short range wireless data exchange between vehicles in a short range intended to offer significant safety improvements.

data and communications will support a new generation of active safety applications and safety systems. V2V communications, USDOT believes, will enable active safety systems that can assist drivers in preventing 76 percent of the crashes on the roadway, thereby reducing fatalities and injuries that occur each year in the United States.

Connected Vehicle Safety Pilot Model Deployment

The Connected Vehicle Safety Pilot Model Deployment Program is the world's largest real-world test of DSRC-based connected vehicle communication technology with approximately 3,000 vehicles operating on public streets in Ann Arbor, MI, USA, for a period of one year (August 2012 to August 2013). The model deployment is being conducted by the University of Michigan Transportation Research Institute (UMTRI) as part of a US $22 million partnership with USDOT. The pilot is designed to determine how well the vehicle wireless communication technology works in real world conditions as well as the effectiveness of V2V and V2I systems in improving road safety. According to the UMTRI Safety Pilot website, it is being described as a "scaled-down version of a future in which all vehicles will be connected."[1] To test the effectiveness of V2X technologies, the model deployment vehicles will wirelessly send and receive electronic data from each other and the infrastructure. In the event of specific hazardous traffic scenarios such as an impending collision at a blind intersection, a vehicle changing lanes in another vehicle's blind spot, or a potential rear end collision with a stopped vehicle, the data will be translated into a warning for the driver of the relevant vehicle(s).

The pilot program has 73 lane miles (117 km) of Ann Arbor roadway fitted with 29 roadside equipment installations that will be used for the V2I portion of the model deployment. Eight major automotive manufacturers are working closely with the USDOT on this research through cooperative agreements: Ford Motor Company; General Motors LLC; Honda R&D Americas, Inc.; Hyundai-Kia America Technical Center, Inc.; Mercedes-Benz Research and Development North America, Inc.; Nissan Technical Center North America; Toyota Motor Engineering & Manufacturing North America, Inc.; and Volkswagen Group of America, Inc.

NHTSA Agency Decision

The National Highway Traffic Safety Administration (NHTSA) was established by the Highway Safety Act of 1970 to carry out safety programs and direct the highway safety and consumer programs established by the National Traffic and Motor Vehicle Safety Act of 1966, the Highway Safety Act of 1966, the 1972 Motor Vehicle Information and Cost Savings Act, and succeeding amendments to these laws. NHTSA is closely following the development of CV technology with its recent analysis concluding that up to 80 percent of all unimpaired crashes' scenarios could potentially be addressed by V2V and V2I technology combined. As the agency responsible for developing, promoting, and implementing programs aimed at ending preventable vehicle tragedies, NHTSA believes that connected vehicle technology warrants consideration for possible regulatory action. NHTSA will use the research data collected through the Safety Pilot to support a major decision milestone in 2013 on V2V safety communications systems. A similar decision is expected in 2014 for heavy trucks.

Depending on what the safety pilot model deployment data reveals, NHTSA's agency decision for vehicle communication safety systems in light vehicles could include one of several options, such as mandatory deployment of the technology in new vehicles, voluntary installation of wireless devices in new cars, or additional research and development. USDOT believes that DSRC at 5.9 GHz is the best communications option at this time capable of effectively and reliably supporting active safety applications. NHTSA intends to follow-up with investigating the regulatory options for medium and heavy duty vehicle technologies in 2014, followed by investigating rule making options for infrastructure in 2015 to support CV technologies and vehicle regulation in place by that time.

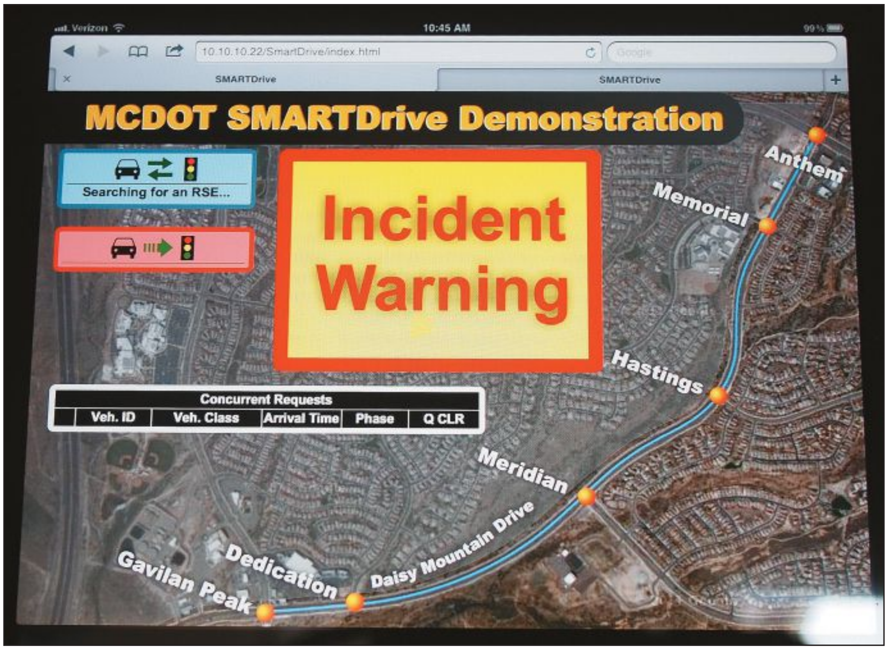

Figure 2. The Maricopa County Department of Transportation (MCDOT) and its partners are developing and demonstrating advanced ITS applications that integrate vehicles together with systematically managed arterial (SMART) roadway systems in Maricopa County, Arizona, to demonstrate the capabilities, evaluate the benefits, and provide a test bed for future SMARTDrive applications.

Figure 3. The SMARTDrive program focuses on connecting CV-equipped vehicles to roadway infrastructure installed on several intersections to demonstrate the capabilities that SMARTDrive supports for transit and emergency vehicle priority.

MCDOT SMARTDrive Program

The Maricopa County Department of Transportation (MCDOT) and its partners are developing and demonstrating advanced ITS applications that integrate vehicles together with systematically managed arterial (SMART) roadway systems in Maricopa County, AZ, USA, to demonstrate the capabilities, evaluate the benefits, and provide a test bed for future SMARTDrive applications. The SMARTDrive program focuses on connecting CV-equipped vehicles to roadway infrastructure installed on several intersections to demonstrate the capabilities that SMARTDrive supports for transit and emergency vehicle priority. An interface to a mobile device shows the participants when priority has been granted and for which vehicles, for both transit and emergency response. Key components of the SMARTDrive demonstration include: six signalized intersections equipped with DSRC radios; Wi-Fi and Bluetooth readers; the installation of a traffic signal priority application; a representative emergency vehicle and transit vehicle used to test application priority logic; a field test for emergency and transit applications; a pedestrian crosswalk application using smart phones to display crossing status; and the collection of detailed vehicle and traffic operations data for post-operational analysis. Outcome from the SMARTDrive tests will provide valuable information to the USDOT CV research program, particularly in the areas of signal applications and the dynamic mobility program.

International Deployment of Cooperative ITS

International deployment of cooperative ITS between the European Commission and USDOT is intended to create a joint framework for field operational tests and evaluation tools; collaboration on cooperative vehicle safety, mobility, and sustainability application research projects; and international ITS standards to support cooperative ITS to increase the value of regional research. The most significant accomplishment of this cooperation is the development of a substantially harmonized core safety message set common to both the United States and Europe: the U.S. Basic Safety Message (BSM) and the EU Cooperative Awareness Message (CAM), which are the result of cooperation between EU and U.S. industry, governments, and standards communities. Simple software reconfiguration is the only requirement for these systems to use both messages nearly interchangeably. This will enable the use of common hardware and substantially common software for products destined for both regions, reducing both the cost and complexity for manufacturers and, ultimately, for consumers. Four signal phasing and timing (SPaT) applications have been proposed for future joint research in the areas of Smart Start/Stop Assistant, Energy Efficient Intersection Control, Traffic Information and Strategic Routing, and Eco-Driving Support.

Figure 4. Car2x communication (also known as vehicle-to-vehicle and vehicle-to-infrastructure communication) is the exchange of information between traffic participants and the infrastructure with the goal of enhancing safety and convenience and optimizing traffic flow.

Car2x Technology Developments in the European Union

Car2x communication (known as V2V and V2I in the United States) is the exchange of information between vehicles and infrastructure with the goal of enhancing safety and convenience while optimizing traffic flow. The higher-level engineering system for assuring Car2x communication is known as the Intelligent Transport System. The basic concept of Car2x communication involves sending and receiving standardized messages over the air interface and enabling interpretation of the status information they contain by traffic participants. The ITS station (ITS-S) keeps the messages up to date based on the momentary traffic situation and either sends them periodically or they are event-driven. The most important status information is transmitted via the message types CAM, Decentralized Environmental Notification Message (DENM), SPaT, and Topology Specification (TOPO).

The European Institute for Telecommunication Standards (ETSI) has already specified the CAM and DENM messages. SPaT and TOPO are currently handled on a project-by-project basis. This system gives the ITS-S of the receiving traffic participants, e.g. a vehicle, the opportunity to acquire information about the immediately relevant traffic situation over a broad area and to warn the vehicle driver, if necessary, or even intervene in vehicle control. BMW and Siemens demonstrated in 2010 a trial system that transmits data between traffic lights and the vehicle to optimize the automatic engine start-stop function and the recovery of braking energy when approaching a traffic light. Current vehicles use sensors to constantly gather information about such things as speed, the environment, or the traffic ahead. Networking the cars makes it possible to warn the vehicles behind about icy roads, traffic jams, or similar situations. Energy efficiency can be improved and fuel consumption reduced if the automatic engine stop-start system from BMW Efficient Dynamics knows the traffic signal cycles.

Technology Scan and Free Webinars on CV

The *Technology Scan and Assessment* is a series of ongoing studies available for free and either as live or recorded webinars that track trends, technologies, and innovations that could influence, or be leveraged as part of, next-generation intelligent transportation systems within a 5- to 7-year time frame. The webinar series covers a number of new technology-enabled systems that may potentially interface with a future DSRC "connected vehicle" core system. Past webinars include What's Driving All This Driving, Innovation in Machine-to-Machine (M2M) Platforms, Applications and Standards, Fourth Generation Wireless Infrastructure—Long Term Evolution, Advanced and Heterogeneous Networks (HetNets), and Computer Vision and Intelligent Transportation Systems.

Autonomous Cars—Are We There Yet?

An autonomous vehicle fulfills transportation capabilities of a traditional car while sensing its environment and navigating on its own using such techniques as radar, lidar, GPS, and computer vision with the key distinction being that it is not driven by a human. Advanced control systems interpret the information to identify appropriate navigation paths, as well as obstacles and relevant signage. Autonomous vehicles typically update their maps based on sensory input, such that they can navigate through uncharted environments.

One of the most significant obstacles to the proliferation of autonomous cars is the fact that they are illegal on most public roads. The Nevada Legislature passed a law in June 2011 to authorize the use

Figure 5. The vision for connected vehicle technology is for each vehicle on the roadway to communicate with other vehicles, enabling a new generation of active safety applications and safety systems.

of autonomous cars, becoming the first jurisdiction in the world where autonomous vehicles might be legally operated on public roads. The bill was signed into law by Nevada's Governor on June 16, 2011. According to the law, the Nevada Department of Motor Vehicles is responsible for setting safety and performance standards, and the agency is responsible for designating areas where autonomous cars may be tested. In September 2012, California passed a bill allowing the legalization of driverless cars in the state of California, which also requires the California Department of Motor Vehicles to draft regulations by 2015.

David Frigard of Frost and Sullivan reported at a CNN Silicon Valley Future Cast on May 14, 2013 that seven states have legalized driverless cars so far. To quote Mr. Frigard, "The technology works today. We aren't talking about a flying car. We are talking about a car that works today." To quote New York Times technology editor John Markoff, from the same FutureCast "Four companies (Audi, Mercedes, BMW, and Volvo) will have automated cars in the market in the next 12 months. We are about to enter this great social experiment."[2] Brad Templeton, former Chairman of the Electronic Frontier Foundation stated, "Cars will be sold by comfort and pleasant experience, not acceleration. Children might say, "Are we there already?" instead of "Are we there yet?" The topic of the CNN FutureCast could possibly surprise most people, but not technologists, and was titled, "The Future of Travel: How Driverless Cars Could Change Everything."[3]

Conclusion

Automobiles and infrastructure that supported driving has been in a slow state of evolution for more than 70 years. The pace of transformation in transportation technology to enable smart drivers has accelerated in the last two decades through the adoption of ITS, GPS, and in-vehicle safety systems. The industry is currently moving towards the transformative phase of technology evolution leading to smart cars. What is to come is the phase of driverless cars whose impact on auto driving or infrastructure or auto insurance is likely to be extremely disruptive and dramatic, but it is not very clear how this will happen. It is analogous to being on one end of the shore and being able to clearly see what life on the other shore looks like, but having no clear bridge to getting there. It is extremely important to note that human ingenuity overcomes these challenges in the long run, but rarely gets it right the first time. The profession needs to embrace change and thrive, as transportation is on the cusp of being transformed by the digital revolution. Resisting change due to the uncertainties it brings along will diminish the importance, and will be the "Kodak moment" in transportation otherwise. ■

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